HYDRO-ELECTRIC DEVELOPMENTS

PLAYER

NOTES

ON

HYDRO-ELECTRIC DEVELOPMENTS

BY

PRESTON PLAYER

NEW YORK
McGRAW PUBLISHING COMPANY
239 West 39th Street
1908

PREFACE.

The interest which has been manifested by investors, capitalists and bankers in schemes for utilizing water powers has created a demand for a general treatment of the subject, which deals particularly with the commercial side of such enterprises. Many water powers have undoubtedly been developed without giving sufficient consideration to the subject or the principles involved, but enough developments have been made to furnish data which may be made use of in the future. It is therefore the object of this short discussion to indicate, as far as possible, the information wi[illegible] be obtained in order to afford a definite basis for forming a decision as to the merits of any proposed undertaking. The idea is to treat the subject from a different point of view from the one usually taken and to avoid as far as possible a discussion of principles of engineering which have been very thoroughly worked out and treated by a number of writers of ability.

Let us assume therefore that good engineering advice may be obtained and we may determine with fair accuracy the possibilities of utilizing the power for commercial purposes.

The first information, therefore, which we desire to obtain is: What will be the cost of making the development? and: What will be the receipts which we may expect from the under-

taking? The answer to the first question can probably be obtained by engineers with commercial accuracy. The answer to the second question, is usually only obtained by an extended examination of the market in which we desire to dispose of our product. Since the price at which electric energy is sold, is dependent upon the cost of generating the same, it is of first importance to determine the cost of producing electric energy by the cheapest method which is now in use or may be used in the locality which we desire to serve. Having secured this information we are in a position to compute the price at which the water power company must sell energy to the various classes of consumers. The science of generating electric energy has progressed to such a degree that one must realize pretty thoroughly what competition means, before engaging in a water-power enterprise. I have tried to present the subject in such a manner, that anyone with the help of men who have given special attention to the various problems involved, may form a judgment of chances of profit which may be expected from an undertaking.

P. P.

Boston, June 1, 1908.

CONTENTS.

Notes on Hydro-Electric Developments.

CHAPTER I.

PRELIMINARY DETERMINATIONS.

The proposition to develop a water power at a given place, is very often originated by an active minded inhabitant of the region where the power is situated. The promoter usually is joined by a contractor, who desires to do the construction work and these two set out to interest capital in the enterprise.

The subject is brought to the attention of the banker or capitalist in various degrees of completion. Sometimes the idea only is presented. Sometimes certain rights of more or less value have been secured with a general idea of controlling the situation. The plan may be legitimate and warrant further investigation or it may appear at first sight entirely impractical. The value of the work which has been done and the value of the rights, if any, which have been secured, are often very much exaggerated in the minds of the promoters, but after frequent repetition to less interested listeners their ideas begin to assume more rational proportions. If the scheme is worth investigating at all, the first thing which we desire to know is:

I. What is the actual property offered for sale and at what price?

Has any real lien been secured which gives the promoters anything to sell or simply are we asked to buy a more or less indefinite idea?

Secondly we must find out:

II. What land if any has been purchased or placed under option and what water rights are included in the purchase or option?

From these two questions it is generally easy to form an idea of the worth of the work which has been done.

III. The information which we wish to secure next is as to the height of the fall which occurs at the site of the proposed development and the distance in which this fall takes place.

From this information we should be able to form a very general idea as to whether the development which will utilize the flow of stream will be an expensive or inexpensive one to make.

It of course being the general presumption that if the fall occurs in a long distance, the necessary construction work to utilize the water will be much more expensive than if the fall occurs abruptly.

IV. The previous questions as to the character of the stream, generally bring up the subject as to what flowage rights are included in the title to the property which it is desired to use.

V. Since the flow of streams is of a very variable nature, varying as to months and years, it is im-

portant to know whether any gaugings of the river have been made and if so by whom and for how long a period. If these records have been kept in a systematic manner we must of course have this information.

VI. Assuming that the sight of the proposed development is adjacent to a market where the energy can be sold, we must know what is the estimated cost of development and the former experience of the persons making the estimates.

VII. As affecting the sale of the energy, we must learn what is the nearest power that has been developed upon this or any other river. If a power has been developed upon the one in which we are interested, we must investigate why the other site was chosen rather than the one now under consideration.

VIII. In addition to knowing what powers have been developed we must endeavor to ascertain what power may be developed, which will come into competition with the scheme which is submitted to us.

IX. If a power has been developed above or below the site which we are contemplating, it may materially affect our plans, either, on account of the other company holding back water or our backing up water on our neighbors wheels.

X. The Government Reports should be one of the first sources of information consulted in checking up the information which has been presented.

XI. Having made ourselves certain that a power

may be developed at a reasonable cost, and that there will be a market for the energy, we must start the preliminary examinations which will furnish information upon which to base more definite conclusions.

CHAPTER II.

METHODS OF PROCEDURE.

When it has been decided that the enterprise warrants further investigation and expense, it is generally customary to get a sufficient hold upon the promoters or vendors so that the proposition may be taken up advantageously should the examinations indicate it to be of value. The first step is to obtain some definite understanding as to the value of the work already done. This usually is rather difficult and is subject to many differences of opinion. The ideas which promoters have are as numerous as the sands of the sea and the importance of their own work is usually very much overrated. They usually propose that the investor puts up all the money, takes all the risk, and divides with them the profits, if any are made in the enterprise.

A fair way, to arrive at a settlement however, is to call for a statement of the money already expended and the amount of the time which has been spent. A price should be set upon all the work which has been accomplished, and the promoters should give the banker an option upon the property for a sufficient length of time to allow him to make such investigations as he may think are necessary to satisfy himself of the merit of the undertaking.

The consideration for the option is that the

banker will undertake the examination and proceed with due diligence. If the scheme is of any value the information thus gained would be of advantage to the promoters, even though the banker should not care to carry out the enterprise. The investigators are to be allowed to cease work at any time they may decide to drop the matter, in which case any additional rights secured are to be turned over to the promoters. Should the bankers decide that the proposition is a meritorious one and desire to proceed with the development, they are to have all existing rights and property turned over upon payment of the stipulated sum. The following is a suggestion of the general points to be covered in an option:

Statements and Agreements of the Vendor.

I. Authority to sell from whom derived.
  (A) Agreement as to date and place of transfer.
  (B) Guarantee of ability to transfer property upon a given date.

II. Terms of sale.
  (A) Disposition of cash on hand.

III. A complete description of the physical property.
  (A) Guarantee of condition at date of transfer.

IV. Statements regarding legal conditions.
  (A) Organization of company.
  (B) Titles to property.
  (C) Franchises.

V. Agreements regarding legal matters.
  (A) Pending suits and claims.
  (B) Future suits arising from acts of vendor prior to date of transfer.
    (1) Provision for giving bond to hold purchaser harmless.

VI. Statements regarding financial condition.
  (A) Cash on hand.
  (B) Inventory of supplies.
  (C) Materials ordered but not paid for.
  (D) Assets.
  (E) Liabilities.
  (F) Earnings.
    (1) Gross.
    (2) Net.

VII. Agreements regarding management of property until date of transfer.
  (A) Under whose authority.
  (B) At whose profit.
  (C) At whose risk.

VIII. Agreements as to meetings of directors prior to date of transfer.
  (A) Date of resignation of officers.

IX. Agreements and statements to be binding on heirs and assigns.

The attorneys who are to have charge of the legal work should if possible have done work before of a similar character, as they are called upon as soon as the general investigation starts, to examine the laws relative to the sale and distribution of water power and electric energy. An

examination should be made at once of all water and flowage rights that have been acquired or which it is anticipated will have to be obtained. The owners of all property to be hereafter acquired must be looked up, and the laws relating to the acquisition of land to be used for private rights of way for pole lines must be carefully considered. The work of obtaining franchises in the localities where power is to be distributed must be started and the provisions of the franchises already obtained examined.

CHAPTER III.

ENGINEERING EXAMINATION.

A preliminary examination by electrical and hydraulic engineers is usually made to check up the data which has been submitted, to establish the amount of power available at all times and the cost of developing the same. The work is usually divided into two divisions, a hydraulic engineer having charge of determining the flow of the stream and making preliminary plans for the reservoirs, dams, etc., an electrical engineer working out the problems of installation, transmission and distribution. As was previously pointed out it is not the purpose of this discussion to describe in detail the methods already perfectly well known for obtaining this information. So that only a very general outline will be given.

Since a stream drains a certain natural territory the extent of the water-shed has a great bearing upon the amount of flow and its regularity. The engineering report therefore, must contain maps showing the position, character and extent of the water-shed.

The water which falls upon the water-shed, runs into the streams, runs into the ground and evaporates. It, therefore becomes important to secure all the available information as to the rainfall, run off and evaporation. This information can usually be best presented in the form of tables.

The records of flow of many rivers have been kept for a number of years and this data if available together with all confirmatory gaugings must be presented in tabular form.

Frequently it happens that the older residents in the neighborhood of rivers have marks which more or less accurately record the height to which rivers have risen upon this or that occasion. This information is of value in assisting us to form ideas of the happenings in the past.

The tables showing the amount of water which will pass over the dam may indicate that if it were possible to supplement the flow of the stream during certain months in the year, a much greater amount of power would be available. In this event it is useful to prepare statistics showing the quantity of water which would have to be added to the stream each day to produce the power which we desire to obtain.

If it is possible to store the water by building reservoirs these tables furnish us with certain information as to their size, etc. It may, however, be imprcaticable to furnish the water at the desired times so that a set of tables which show how much mechanical power, such as steam power, must be installed to supplement the river flow may have to be prepared.

The stream may be susceptible of various degrees of development so that the desired information usually calls for a good deal of painstaking, investigation and the preparation of maps and plans

which show the details of the different aspects of the development. What the engineers desire to ascertain is the best development which the country will afford. The best meaning the greatest number of useful horsepower for the fewest dollars of investment. It may be found before the examination has progressed very far that the cost of the work will be more than it is wise to expend, but providing the project is feasible what we desire to determine is the average cost per horsepower for all rational developments. Later in this pamphlet will be discussed how much it is wise to pay to make any installation.

In considering questions involving water power the engineer is not dealing with an exact science. There may be at hand satisfactory records of rainfall, flow, etc., yet we are of course making our first important assumption when we consider that the history of the past will be an accurate guide as to what may take place in future.

If it is advantageous to construct an expensive dam to utilize the river flow there must even in the best designed structures be a certain element of risk.

The failure of a dam may occur in one of the following ways:

1. Dam sliding down stream.
2. Dam overturning.
3. Dam springing a leak.
4. Water changing channel and cutting around end of dam.

5. Water undermining dam.
6. Insufficient spill way.

The position which the dam is to occupy in a stream is consequently very important and must be chosen with extreme care. It is therefore essential to obtain an accurate idea of the foundation upon which the dam will rest, before a definite estimate of the cost of the structure is made. Plans giving the general design of the power plant and machinery and the method of power transmission are necessary in the preliminary considerations, as they are used as a basis of estimating costs. Upon the results of the information obtained in this examination will depend very largely the decision as to whether the proposition is one which is likely to show enough margin of profit if developed, to assure us that the money which we are to spend for further examination will be justified. If the reports are favorable we are now ready to make a detailed examination of the market.

CHAPTER IV.

THE EXTENT OF THE MARKET FOR ENERGY.

The examination of the market for energy is made to determine first, the amount of power which is being used; second the number of hours per day the power is employed. Third, the cost of producing energy for the uses which are being made of it. In supplying energy the water power company may have to compete with energy furnished by:

1. Steam engines.
2. Gas engines.
3. Oil engines.
4. Electric light companies.
5. Street railways companies.
6. Other water powers.

The first step therefore, is to make a detailed canvas of the existing consumers and tabulate the results of the examination (see table page 14.)

In considering the question of selling energy the number of hours it is to be used each day becomes a very important question. The reason for this is that the saving in generating electric energy by water rather than by fuel, is mainly the cost of the fuel saved. If the energy is used for but a few hours, the saving of course is not so great as if it were used continuously. Moreover if the cost of the water power installation is much more per horsepower than the cost of the steam

machinery the excess of interest charges upon the water power plant may more than outweigh the saving in fuel so that steam may be the cheaper.

In order to determine therefore how much

	Hours duration of load	Average hp.	Peak hp.	Character of load	Time of day of Maximum load
Electric Light Cos'.........					
Street Railways					
Manufactories using........					
over 100 hp.....					
over 50 hp......					
over 25 hp......					
over 5 hp.......					
Office Buildings					
City Lighting..					
Commercial Lighting.....					
Railroad Companies.......					
etc., etc.......					

business may be obtained, we must prepare some estimates of the cost of generating energy for various uses. Let us see what conditions we will have to meet: First of all there is usually a certain time in the day when every one wants power or

light. In northern localities this time varies according to the different seasons. As the factories are running and using power at five o'clock, in winter, owing to the shortness of the day the lamps are turned on and the people in the stores and houses are also forced to use artificial light. There is, therefore, thrown on the station at this time, what is called a "peak load." Of course, the station or power company is forced to supply machinery to take care of this demand. Some of the machinery which is in use at this time of day may remain idle all the remainder of the twenty-four hours. Since the interest upon the money invested in this machinery and the contingent expenses are a very large amount compared with the cost of generating the energy for say two or three hours, it becomes very important to the power company furnishing electric light to know when and how long a customer is to use the current.

There are, on the other hand, customers who use the energy continuously all day; some use it only intermittently. All these questions have an important bearing upon what it costs the consumer for his energy and what it will cost the power company to supply it. Another phase of the question becomes apparent upon analysis and that is, that it is often profitable to furnish two or more customers neither of whom would be profitable alone.

Before proceeding to discuss the cost of manu-

facture of energy it may be of interest to quote from the twelfth census of the United States, Volume VII, Part I, Chapter IV.

"Of the total power used in Manufactures during the census year, steam engines furnished 8,742,416 horsepower or 77.4 per cent. of the aggregate; water wheels supplied 1,727,258 horsepower or 15.3 per cent.; electric motors 311,016 horsepower or 2.7 per cent.; gas and gasoline egnines 143,850 horsepower or 1.3 per cent., and other forms of mechanical power 54,490 horse power or four-tenths of 1 per cent." We find that there were employed in the United States the following amounts of power:

	Amounts.	Per cent. of increase.
1870	2,346,142 horsepower	
1880	3,410,837 " "	45.3
1890	5,954,655 " "	74.5
1900	11,300,081 " "	89.7

These last figures are furnished to show the manner in which the power is generated and the remarkable growth which is taking place. An indication of some of the possibilities of the future is as follows: Census Report, reference same as above.

"The modern office building, often housing a population equal to a small town, is almost wholly a creation of the past ten years and the power required in these great structures, not only for

lighting purposes, but for the operation of elevators, pumping water, compressing air, and operating refrigerating and ventilating machinery, forms a large item when the number of these buildings in the United States is taken into consideration."

CHAPTER V.

COST OF ENERGY MANUFACTURE.

Since it has been shown, that the load upon a power plant varies at different times in the day, we find that this variation is a very important subject. The extent of the variation is measured by what is known as a load-factor and is usually taken for a 24-hour day. It is defined as follows: The ratio of the average load to the maximum load. Let us see how this information is arrived at. Meters have been invented which measure the kilowatt-hours which have been consumed. The kilowatt-hours may be compared with the cubic feet of gas or water at a certain pressure, and may be changed to horsepower-hours by a very simple arithmetical calculation. If we divide the consumption of energy, measured in horsepower hours, during 24 hours by the maximum horsepower load on the plant multiplied by 24, we obtain a fraction or decimal which is known as the load-factor. If the load were very steady during the entire 24 hours the load-factor would approach unity or one. Since, however, energy is used for different purposes and in different ways different plants have different load-factors. It is, therefore, perfectly conceivable that the load of two or more plants may be of such a character that if one large plant should undertake to supply the other plants that load upon the large plant would be more

nearly even than upon any of the individual plants. As a matter of fact this may be brought about, more or less, by the selection of one's customers.

Engines in many factories have very varying loads and are operated consequently under unfavorable conditions. An engine must be capable of taking care of the maximum load which it may be called upon to carry, with the result that it may be running most of the time very much under loaded. Since the engine does not work constantly at its maximum efficiency, the coal consumption per horsepower-hour is generally much larger than would be the case were the engine running at its normal load.

It is obviously misleading therefore in calculating the cost of running an engine, to take as a basis of estimate the number of pounds of coal consumed by engines in tests under favorable loads with expert firemen, etc.

We generally see in regulations for tests rules for having the fire appear in this or that manner before the test and for producing the same result at the end of the run. The coal of course being weighed during the test. The information so derived has many uses, but the average fireman in a factory which runs eight to ten hours, builds up his fire from the bank of the night before and closes the day's run with everything going full blast. Afterwards he fixes and banks his fires for the next day's run, all of which consumes coal.

The company which supplies energy to a number of small users gains greatly over the small

producer, in that as the number of users increases the combined load becomes more nearly steady and consequently the company's machinery may work at better efficiency. The idea of a number of small units tending towards constancy is similar to the theory that a bank's deposits are subject to less fluctuations as the number of small depositors increases.

Again, in furnishing electric energy it has been found that if we are to supply a number of motors of from one to 25 hp. capacity, that the chances of all the maximum loads occurring at the same time become very small and that we need only provide a generator to furnish current to these motors of $\frac{1}{3}$ the sum of their maximum demands. In supplying current to motors of from 200 to 300 hp. in size we are generally required to make a provision for 0.5 the maximum connected load to full maximum connected load, according to the duty which the motors perform. A power plant, therefore, has very marked advantages over the small power producer, in that,

1st. The capacity of the generating units is less than the sum of the individual maximum demands of the motors.

2nd. The efficiency of the unit generating the power supply is greater in that the load can generally be better apportioned to its requirements.

3rd. There are other savings which can be effected in producing power in large quantities in that the expenses do not increase in direct proportion to the size of the units.

Let us first consider what it costs a manufacturer having a 200 hp. engine to generate energy. We will take this case under the supposition that if we can sell this man electric energy we shall be able to supply factories using less than this amount.

Upon looking over the factory we find we will say that energy is being generated by a modern direct-connected engine and generator supplying a number of individual motors. We take this case since the energy is being generated at less cost than would be the case were belts used in driving shafting. We find that one fireman and one engineer in charge of the electrical plant, are employed. Steam is used during the winter months to heat the factory. An appraisal of the plant upon a horsepower basis would probably show the cost to be as follows:

	Cost per horse-power.
Engine and generator	$50.00
Switchboard and wiring	10.00
Boiler and piping	15.00
Erecting plant	10.00
Foundations	7.00
Feed pumps	2.00
Engine and boiler house	13.00
Chimney and flues	8.00
Miscellaneous	5.00
	$120.00

This figure $120.00 per hp. is perhaps an average cost of installation of a small plant.

We will now figure what the fixed charges amount to upon this investment.

Depreciation we will consider as 5 per cent. per year, since if we take the average life of the equipment as about 15 years, upon reference to the sinking fund tables we learn, that if 5 per cent. of the principal sum is put aside each year and invested in funds yielding 5 per cent, that the fund amounts at the end of this period to the principal sum.

Assume money to be worth say 6 per cent. The following table represents therefore something like the fixed yearly expenses:

Depreciation	5	per cent.
Repairs	3	"
Taxes	1	"
Insurance	0.5	"
Interest upon investment	6	"
Total	15.5	"

Say 15 per cent.

In order to operate the plant it is necessary to have two men, one fireman at $2.00 per day and one engineer and electrician at $3.00, making total wages for a 300 day year of $1500 or $7.50 hp. per year.

Upon examination of the type of engine we may estimate that such an engine would require 3.5

pounds of coal per hp-hr., for a steady load with everything working favorably. On the other hand, when we come to make an examination of the coal records for the period of the year when the heating apparatus was not in use, we will find very likely that this engine may be consuming from 4 to 8 lbs. per hp-hr. according to the load factor, quality of coal and the fireman.

The average coal consumption including starting and banking fires we will say is not far from 6 lbs. per hp-hr., and the average load upon the engine about 100 hp. The coal consumption is therefore 6000 pounds per 10 hour day, 1,800,000 lb. a year or 900 short tons, at say a cost of $4.00, making the total coal expenses $3600 per year, exclusive of the coal used for heating. As the engine is rated at 200 hp. this is $18 per rated horsepower-year for coal. The items which go to make up the cost of a horsepower-hour are the following:

Coal	$18.00
Wages	7.50
Fixed charges	18.00
Miscellaneous	1.00
	$44.50

This is at the rate of $8900.00 a year.

It is now important to estimate what energy will have to be sold to this manufacturer for in order to get the business. In the first place he will probably not desire to sell his own plant and

will wish to keep it as an insurance against high rates. However, he will expect us to pay this insurance and we will probably wish to, as the plant would give us trouble if moved somewhere else. If we say that we will pay him 5 per cent. upon a fair value of his investment, he will believe we mean business. If we sell him energy, how are we to effect the labor bills? He will probably need to employ one general man to have supervision over the electric installation which of course will consume a very small proportion of his time. This man can also keep up the fire in the boiler in winter which will now be used for heating.

Considering the time that he is employed upon this work we may say that one-half of his time should be charged to electrical plant and one-half to general service in the building. We pay him say $2.50 a day. The electric installation therefore bears a charge of $375.00 a year. We find, let us say, that on account of the load-factor at this plant, that if we could take this business in connection with other power consumers that a reserve of 100 hp. would take care of the special load.

Let us assume then, that we make the manufacturer a price of $30.00 per hp-yr., or for 200 hp-yr. $6000. His wages cost him $375 and the 5 per cent. which we allow him upon his plant adds $1200.00, making a total of $7575.00 or he would be paying gross $37.87 per hp-yr. as against

$44.50, which is a saving of $1325.00 per year. We probably will find that he has had trouble with his machines, with his men, and has suffered from breakdowns. This saving, together with the security of being supplied by a company with ample power should appeal to him. In addition to this, as soon as he becomes one of our customers he has the advantage of being able to call upon us any time for advice or repairs.

On the other hand, we nominally take his business at the rate of $30.00 per year, but in reality his average power consumption is 100 hp. so that we are obtaining $60.00 per hp-yr. for the machinery which we are required to reserve for him. If the power is used 10 hours a day for 300 days or 3000 hours per year, a rate of $60.00 amounts to $.02 per hp-hr.

CHAPTER VI.

CENTRAL STATION ECONOMICS.

We have now learned what price we should have to make in the locality under investigation in order to obtain the business of one class of consumers. We investigated this class under the assumption that if we could afford to take this business we could sell energy to smaller consumers. It may happen that there is in the field a competitor perhaps an Electric Light Co. selling electric energy. We probably cannot examine our competitors books but it is necessary for us to know at any rate what would be the cost of generating energy in a well designed station using, we will say, coal for manufacturing steam. If we have this information we can tell which of the following three alternatives we had better adopt granting each were possible:

1. Compete with the existing company.
2. Purchase the company.
3. Sell electric energy to the company.

As there is no satisfactory method of storing electric energy in the sense in which we are accustomed to think of storing gas in holders and water in reservoirs, we cannot generate it during the portion of the day when the load is light and supply it when it is needed, but we are obliged to have sufficient machinery on hand to provide the energy as the customers desire it. This state-

ment is modified at times when the nature of the demand which causes the peak load is of such a character that it is more convenient or cheaper to use an electric storage battery than to purchase the machinery which the storage battery is designed to replace.

For practical purposes, however, let us consider that we must have machinery of sufficient capacity in the plant and wires of sufficient size to supply the demand which is made upon us by our customers at the time when the demand takes place.

It will at once be seen that there are certain expenses entailed in keeping this machinery on hand which are fixed by the amount of or power of the machinery; there are also certain variable expenses depending upon how long this machinery is run. In addition, there are certain miscellaneous expenses which are not dependent upon the power of the plant or the cost of supplying the electric energy.

The general method, therefore, of arriving at the cost of making electric energy is to divide the expenses into three somewhat arbitrary subdivisions.

1. Expenses which are fixed by the capacity of the plant and the demand upon it.

2. Expenses which are variable and dependent upon the amount of energy supplied as measured by horsepower-hours or kilowatt-hours.

3. Expenses not strictly proportioned to either rating or output, but which are not of sufficient

magnitude to prohibit them from being included in one of the other classes.

Group I.—Expenses dependent upon the cost of demand:

Rent or interest on cost of land.

Taxes, insurance and legal expense.

Maintenance of distributing system and customer's equipment.

Salaries of officers and clerks.

Office expenses.

Group II.—Expenses dependent upon cost of supply:

Fuel.

Water or interest on money spent in providing. water supply.

Lubricants and waste.

Repairs engines, boilers and electric plant.

Group III.—Miscellaneous expense:

Advertising and soliciting (Include in Group I.)

Renewals of customers' lamps (Include in Group II.)

Repairs of arc lamps (Include in Group II.)

Experience has shown that in general the maximum load on a plant is approximately 75 per cent. of the sum of the customers maximum demands. As it is not generally safe to count too definitely upon this, a well designed plant must have some reserve power, to be upon the safe side we will figure that the power rating of the station must equal the sum of the customers maximum demands.

Having made this assumption let us now figure what is the cost of demand. Judging from past history and what is likely to take place in the future it is probably not very far from the truth to estimate that the average life of station machinery is about 15 years. Upon this assumption at the end of 15 years a fund should have been accumulated which would be sufficient to replace the machinery which would then have become out of date. We find that a sinking fund of 5 per cent. of the structural value of a plant set aside each year and the fund invested in securities yielding 5 per cent. is equivalent to the principal sum in about 15 years.

The average cost of installing a horsepower in an electric plant, including distributing system, let us take at $225. That is, $125 for station plant and $100 for lines, distributing appliances, etc.

If money is worth 6 per cent, and taxes amount to 1 per cent., and depreciation to 5 per cent., the fixed charges amount to 12 per cent. of $225 each year, or $27.00 a year, whether the plant is used or not.

Experience has shown that the expenses detailed under No. 1 which make up the cost of demand for plants doing largely an electric lighting business amount to from $15.00 to $20.00 per horsepower-year. Taking the lower figure the total cost per year is $42.00 for each rated horsepower of machinery installed. It should be noted that this amount is what it costs the company whether

the plant serves the customer or not and amounts to about 11.5 cents per day for each rated horse-power of machinery installed.

An examination of the station costs or an estimate may show that the cost of supply is say 0.75 cents per hp-hr., depending of course upon the size of the plant and the demand-factor, cost of fuel, etc.

The miscellaneous expenses will amount to say 0.5 cents per hp-hr. We are now in a position to make up a table of costs of supplying 1 hp-hr. of electric energy.

Hours use of maximum demand	Cost of demand. Cost of miscellaneous. Cost of supply one hour.	11.5 cents. 0.5 cents. 0.75 cents.
		Cost per hour of use (cents).
1	11.5 + .5 + .75	12.75
2	5.75 + .5 + .75	7.00
3	3.8 + .5 + .75	5.05
4	2.8 + .5 + .75	4.05
5	2.3 + .5 + .75	3.55
6	1.9 + .5 + .75	3.15
7	1.6 + .5 + .75	2.85
8	1.4 + .5 + .75	2.65
9	1.3 + .5 + .75	2.55
10	1.1 + .5 + .75	2.35
20	.55 + .5 + .75	1.80
24	.5 + .5 + .75	1.75

The above table is based upon the principle that since the plant is ready to serve the customer whether he uses electric energy or not, the expense must be borne by him. The cost of demand was found to be 11.5 cents per day for each rated horsepower of machinery installed. If the customer uses one horsepower but one hour each day in the year the rate charged must include this sum together with the miscellaneous expense and the cost of supply. Whereas if the energy is employed at the rate of one horsepower for two hours a day each day in the year, the cost of demand is divided equally between each hour and the miscellaneous expense and cost of supply added. The cost of one hour's use of the maximum demand of one horsepower amounts to 12.75 cents per day or $46.53 per year. For two hours use per day of one horsepower the charge is at the rate of 7.00 cents per hour that is 14.00 cents for two hours use or $52.10 per year.

The table of course being based upon the assumption that the power which the company is called upon to furnish will be required at a time when the station is carrying its maximum load. Putting the matter in another way, the above table shows the actual cost to the company in cents per hp-hr. in supplying electric energy to customers whose maximum demand ever comes at the time the station is called upon to furnish its maximum load or in other words whose energy is used at the peak of the load of the station.

The peak load upon a station varies in amount

in different months in the year, the maximum in northern climates usually coming around Christmas time and the minimum in summer. All the rates which the electric light company has made and which can be ascertained should obviously be studied in connection with the cost figures. To compete successfully with these costs the water power company will obviously have to sell energy at a price which will not permit the electric light company to undersell at a profit. From the general situation, the Water Power Company should be able to judge pretty well at what price it can get the business.

The next question which we are called upon to investigate is at what price can we afford to sell to the electric light company. Let us consider first the case which of course would be the most difficult to meet, namely, the purchase of electric energy from the water power company which would entail the electric light company shutting down a corresponding rated horsepower of machinery. The electric light company, by allowing its machinery to remain idle would save only the items entering into the cost of supply.

If the water power company sold to the electric light company directly it would save many of the expenses which are entailed in the distributing energy.

Let us, for the sake of example, assume that \$28.00 per horsepower-year will repay the water power company for its current. Provided the water power company has an abundance of water,

on hand, it is immaterial whether it supplies energy one or ten hours a day; it, however, makes a very great difference to the producer, with a steam or gas engine, how long he is relieved from burning fuel. Let us prepare a table showing what is the equivalent of $28 per hp-yr. reduced to an hour basis per day, so that these figures can be compared with those showing the saving to the consumer for every hour that he shuts down his generating machinery and allows the same to remain idle.

No. of hours of use.	Equivalent $28.00 per year. Cents.	Cost of supply.
1	7.67	0.75
2	3.83	0.75
3	2.55	0.75
4	1.92	0.75
5	1.53	0.75
6	1.28	0.75
7	1.01	0.75
8	0.96	0.75
9	0.85	0.75
10	0.76	0.75
11	0.69	0.75
12	0.64	0.75
13	0.59	0.75
14	0.55	0.75
15	0.51	0.75
20	0.38	0.75
24	0.32	0.75

The above figures indicate that the distributing company, when it has the machinery on hand and consequently has to pay the fixed charge, can in this case use the machinery upon loads which last less then 11 hours, to better advantage than it can purchase energy at $28.00 per hp-yr.

Conversely in this case the distributing company

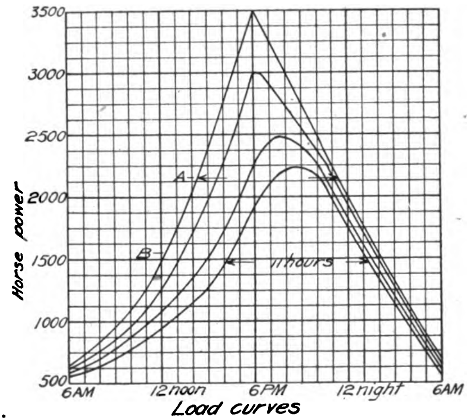


Fig. 1.

can profitably purchase energy which it is called upon to supply for longer than 11 hours from the water power company. To show this better the foregoing exhibit, Fig. 1, gives load curves of the distributing plant for different months in the year. Assuming that the proper working of the power house shifts of men and the banking of fires do not complicate the question too much, some-

where between *A* and *B*, namely 1500 and 2250 hp. would be selected as the amount of energy to be bought.

This purchased energy is known as "firm power." Just where the line of "firm power" would be located between *A* and *B* would depend in practice upon the rate of growth of the distributing company's business and local conditions. It is to be noted, however, that the lower the price we make to the consumer, the higher the lines of "firm power" move up the chart and consequently the number of horsepower the electric light company can afford to purchase increases. By the proper use of the information we should be able to form a pretty general idea of the price we should be called upon to make in order to get the business.

We know how much energy the company could afford to buy and the price. If we purchase the company we know what we can save on the operating expenses and consequently the added earnings upon the purchase price and yet obtain a satisfactory return upon our water power investment.

From the methods of investigation above outlined we can form a pretty definite idea of the price at which the power company would have to sell electric energy in order to compete with the existing company and also how much energy the electric light company can afford to buy from the water power company and the price which it can afford to pay.

The question of the ultimate destiny of the existing company is of course a subject of negotiation but by this investigation we have established a price that we will probably receive for the electric energy as long as the existing company remains in the field.

The principle which we have endeavored to bring out in connection with the sale of energy to lighting companies can be applied with equal value to street railways, and is discussed here for convenience. The curve showing the power consumed at the various periods of the day or in other words the load curve is in general materially different from the curve of a lighting company. The load is likely to be heavier in summer when more cars are running and more business is done than it is in winter, which of course is different from the lighting load. The form of the curve is also different in that there is a peak in the morning when people are carried to work and also one at night. A study of these curves for the various months and for a few years will bring out many interesting facts. A question of course of prime importance as influencing the position of the line of "firm power" is the probable rate of increase of the power requirements. First, we desire to establish a line showing the amount of energy a street railway can afford to buy and shut down its generating machinery provided no growth takes place. We should not endeavor in a rapidly growing community to make a price so low that

this line will be forced up to the highest point. Because the price which we have thus established will be very difficult to increase afterward. If the company is using more energy each year and if we were not going to supply them they would be forced to purchase additional machinery each year to provide for the increased load. For this increased amount of energy the street railway company can obviously afford to pay us more money than they could for energy which would displace the machinery already installed.

The additional "firm power" which we are to supply the street railway each year for its increased business may be only a small proportion of its total load, yet a very substantial proportion of the power which we have contracted to supply originally. We, therefore, should not endeavor to take the largest part of the street railway load which we can get at the cheapest price but we must determine what it is costing it to produce electric energy, for loads lasting different lengths of time. A table should be prepared showing these costs and the same compared with the table giving costs derived from the rate which we desire to make. We should endeavor to get all the business which the rate shows us to be entitled to, with the promise of obtaining the increased business the following years. In figuring power business we are of course to remember that the power company saves the distributing expense. We are sometimes asked, however, to make a

price for the electric energy transformed and ready for use. The price we make must take into consideration the maintenance of the conversion apparatus and the fact that a sufficient sinking fund must be set aside each year to write off the cost when the contract expires.

CHAPTER VII.

SALE OF ELECTRIC ENERGY.

Having determined in Chapter IV to amount of energy that is being used in the locality and the Chapter V and VI the probable price that the water power company can obtain for electric energy. The next step is to analyze the cost of selling and generating electric energy by water power.

Ever since electric light companies began the sale of electric energy for light and power purposes, engineers have endeavored to evolve a satisfactory system for charging for service. A great many methods have been invented, some of them unfair to the power companies, some unfair to the customers, and others unsatisfactory to both. The main difficulty has been to obtain an equitable method of payment for the peak loads. In the chapter dealing with the commercial investigation, the general method was outlined for determining the cost to an electric light company, manufacturing its own energy.

In the case of a water power company it is, within limits, immaterial, whether the power is furnished for two hours or twenty-four hours per day; the main point is that the company must during each day obtain sufficient revenue from each horsepower rating of machinery installed to pay for holding this machinery for the customers benefit.

We saw in discussing this question in the preceding chapter that the charges arising from the readiness to serve entailed certain fixed expenses which were independent of the energy supplied. Excluding the interest and depreciation charges upon the plant the cost of demand is substantially the same whether the power is developed by water or steam or some other substance.

If the water power company has no steam machinery for carrying peak loads of short duration it is plainly evident that if the original cost per horsepower for the water power development were much greater than the cost of installing a horsepower of steam machinery a steam plant could handle such a load more cheaply.

As an illustration of this, take the load of an electric light company.

For three months in the year we may have in some localities a heavy peak load lasting at most four hours. If it costs say $125.00 to install one rated horsepower of steam machinery in the plant, the interest, depreciation and repair charge might bring the fixed expenses to $18.75 a year. The conditions which existed in the plant might admit of handling this form of load without any additional men; the extra coal used might amount to 3 cents per horsepower-day or $2.70 for the three months in other words, $21.45 for handling each horsepower-year of peak load. The water power company could obviously not take this load unless the cost of installation were low and even then the contract would be tying up machinery

which might be used in supplying a different kind of load where the earnings might be three times as much.

An inspection of the load curve of the electric light company very probably would show that the power could be split up into peak load power and a "firm" 15 hourpower. The cost of generating this block of "firm power" to the electric light company may be nearly $50 per hp-yr., not considering the interest upon the investment. The water power company could undoubtedly afford to take this part of the load at a price that would save the electric light company money. The electric light company on the other hand would hardly care to contract for the peak power for more than it cost to generate it, yet this amount might not yield the water power company sufficient income. Customers loads also vary in so many different ways that any formula which accounts for this variation only through the use of a load factor is very likely to be very misleading.

The water power company which sells energy is forced to name different prices for different classes of service.

We will, therefore, analyze the cost of selling electric energy to customers using it for,

I. Electric lighting.

II. Supplying small motors under 25 hp.

III. Supplying motors under 300 hp.

IV. Supplying practically continuous load.

V. Firm power of street railways and electric light companies.

In retailing electric energy in relatively small amounts for electric lighting purposes, the cost of demand, is the primary one to consider.

The cost of demand including miscellaneous expenses but excluding fixed charges to a number of companies supplying the larger cities in Massachusetts averaged very close to $20 per horsepower year. These companies supply of course, a certain amount of power but not enough to appreciably affect the cost of demand. This figure is the cost of maintaining the plant and organization in the state of being ready to serve the customer whether the energy is used or not. Money invested in a water power enterprise should yield about nine per cent. in order to keep the principal sum unimpaired.

This is arrived at as follows:

Interest upon investment	5.5 per cent.
Depreciation due to change in art and advancement of science	1.5 " "
Insurance fund to provide for menace due to contingencies commonly called "casualties"	1.0 " "
* Repairs upon plant	1.0 " "
	9.0 " "

* The item of repairs upon plant is commonly included in operating expenses. This item overlapping as it does the depreciation charge is treated here in this manner to avoid complications and permit of an easy method of figuring.

The forming of an adequate estimate of depreciation is very difficult. An assumption usually

made is that the depreciation amounts to 3 per cent. of the value of the machinery and apparatus exclusive of the actual hydraulic development, which is supposed to be permanent. As the value of the depreciating portion of the plant is within limits equal to the non-depreciating portion the figure 1.5 per cent. is perhaps fair. The insurance fund of 1 per cent. which would of course not provide for great devastation but usually should take care of ordinary contingencies and this amount is quite often set aside as a sinking fund to retire 1 per cent. of the bonds yearly. The repairs upon the working portion of the plant amount to about 2 per cent. or 1 per cent. upon the whole investment is usually sufficient to set aside.

The expenses which go to make up the cost of supply, labor and miscellaneous expenses usually vary from $3 to $5 per horsepower-year, depending upon the size and number of the units.

Assuming that the cost of installing one horsepower of water power plant, is in the case which we are investigating $160.00. The price which we must obtain for each hp-yr. of electric energy used for lighting purposes, should the same ever be used upon the peak load of the station, would be as follows:

Cost of demand..................	$20.00
Cost of money...................	
9 per cent. on $160.00..........	14.40
Cost of supply..................	3.00
	$37.40

This would be at the following rate to a customer:
Use of one horsepower for lighting purposes.

1 hour per day	10.2 cents per hp-hr.
2 hours " "	5.1 " " " "
3 " " "	3.4 " " " "
4 " " "	2.5 " " " "

etc.

In order that a company may obtain sufficient information to sell electric energy at retail it is necessary to install a meter which records the customers maximum demand upon the plant in kilowatts or horsepower. Then, theoretically, by multiplying this amount by the price of a horsepower-hour of electric energy we would arrive at the charge which the customer would pay the company for reserving the machinery to supply him with electric energy. As a matter of fact it has been found that when this system is used many customers never turn off all their lamps and that machinery must be kept going to supply energy which is being wasted. A slight modification of the above method is to use a watt-hour meter to show how many horsepower-hours or kilowatt-hours have been used. For instance it may have been found by experience or it may have been estimated that the average daily consumption of energy will last three hours. We wish to place a small penalty upon the customer for wasting energy. The charges therefore, might be made up of two kinds, a fixed charge for every day in the year, called a calendar charge and a small

additional charge based upon using the lamps, called a service charge.

If three hours per day is the average number for which a lamp is used during the year, the fixed daily calendar charge plus the three hour service charge should be so arranged that at the end of the year the power company would receive in the case chosen in the vicinity of $37.40 per year for each horsepower of customers maximum demand. The customer who wasted the electric energy would of course pay more than this sum. Should the watt-hour meter show that the lamps had not been burned the customer would pay the minimum rate, or the calendar charge. Very many modifications of the above system have been devised and many can be worked out, the object being to have the customer pay for the number of horsepower-hours, which could have been produced by the machinery which was reserved for his benefit.

II. Supplying energy to small motors.

In making up a schedule of rates for consumers requiring small amounts of power, it should be remembered that the cost of demand varies with the size of the motor. Furnishing energy for the small motor, say up to 5 hp., requires essentially the maintenance of all the paraphernalia which goes to make up the cost of demand for the lighting customer. The cost of demand not including interest upon the investment, etc., for supplying energy in large quantities probably approaches

very near to $4.00 per horsepower-year. It is very difficult to obtain satisfactory data from enough companies to definitely establish this figure but we should probably not be far out of the way if this amount were used.

As has been previously pointed out it is customary to figure that we can oversell the capacity reserved for small customers three times. Since it is extremely advantageous to sell as much energy as possible in small lots on account of the stability of the load. Small users of energy should be encouraged and they should be given the benefit of the advantages of securing this load.

We probably should not be very far out of the way if we decided to use the following as the cost of demand for small motors.

Horsepower	Per horsepower-year.
Up to 5	$20.00
" " 10	17.50
" " 15	15.00
" " 20	12.50
" " 25	10.00

To these figures must be added the fixed charges upon the plant investment per hp., as was done in figuring the cost of lighting service, plus the service charge, the horsepower used in figuring the amount of fixed charge being the amount actually demanded of the plant, namely for motors below 25 hp., one third of a hp. for each horsepower of motors as has been previously explained.

III. In supplying electric energy for motors of more than 25 hp. and up to 300 hp. the cost of demand would probably run from ten dollars per hp-yr. to five dollars for the larger size equipment. The power company would probably be safe in figuring for these motors that a plant rating equal to from one-half to full connected load would be required.

IV. In supplying energy for a practically continuous load as for electrolytic purposes, the energy rate or power is practically constant day and night. This of course is the most satisfactory kind of load for a power company to have and the cost of supplying the same can be easily figured. Some power companies, like those at Niagara Falls are said to have built up very regular loads by supplying energy to the companies for electrolytic purposes.

V. The supplying of large quantities of "firm power" to street railways and electric light companies reduces the cost of demand to a low figure. In making such contracts the power company is usually called upon to make a rate which is low enough to allow the consumer to let a certain amount of his machinery remain idle. The power company is, therefore, forced to compete with cost of generating the energy only. In the previous chapter under commercial investigation, the question of making rates for this service, was outlined.

At times chances arise for supplying energy to

customers who agree not to use it at the time when the maximum peak load comes upon the station. As an example of this may be cited, a pumping plant belonging to a city, which can usually discontinue pumping during the hours when the power station is called upon to furnish the greatest amount of power.

In figuring the cost at which this business may be profitably taken, since the energy is not to be used at the time when the station is called upon to furnish the maximum power, the fixed charges upon the investment in the machinery used for supplying this character of service may be disregarded as no machinery has been reserved.

The prices at which energy may be sold are consequently reduced by this amount.

CHAPTER VIII.

PRIMARY AND SECONDARY POWERS.

As has been previously pointed out the amount of water flowing in rivers varies with the seasons of the year and during a series of years. The manner in which this variation of flow occurs is of extreme importance since it of course directly affects the amount of power which the power company can contract to deliver. The penalties imposed by contracts for interruption of power supply are very strict and a precise knowledge of what one is in a position to sell is consequently vital.

It is very often the case that if we should take the minimum flow of the stream in the least flow month and least flow year that the amount of power which we would develop would be but a trifling proportion of the average flow and that consequently the dams, etc., would be so expensive in comparison with the power available that the undertaking would be prohibitive. Under certain conditions, therefore, it has been customary to supplement the least flow by the use of pondage, reservoirs and steam auxiliaries.

Another method which has been employed is to allow the customer to maintain the reserve power, and contract only to deliver an intermittent power at a low price for the energy. This form of energy is known as secondary energy and the

price at which it can be sold depends upon its conformity to the customers demands. The value in general of secondary energy is fixed by the value of primary water power in the locality less the fixed charges of maintaining a steam plant reserve, less the probable operating cost of using the steam auxiliary, less a bonus or inducement commensurate with the menace of using a power varying as to regularity.

In making water power developments it is not usually considered conservative to include in the estimate of the gross revenue of the plant any earnings from secondary energy. If any energy can be sold advantageously upon this basis after the development has been made, such earnings would of course be so much gained. The price which a power company obtains for secondary energy is usually low and the cost of producing this class of energy is not very materially different for that of producing primary energy, since the investment charges are practically the same and the operating expense not substantially different.

The common practice is for the power company consequently to maintain all reserves, etc., and sell primary energy.

In every business undertaking we are called upon to determine what risks we may take without overstepping the bounds of conservatism.

Our customers are going to call upon us in all probability for a different number of horsepower in winter and in summer, by day and by night.

What we desire to know is whether the river can furnish us this power at times when the customers demand the same.

So that the question ultimately comes down to how many dollars net a year can a river earn for us. This we must know, to determine whether the development will be financially successful. Since we should by this time know something about the flow of the river, the first step in making these deductions is to plot a probable curve showing the power which we will be called upon to deliver. The method of doing this is to analyze the amount of load which we will be required to carry. For instance, from the data which was obtained from the commercial investigation, we can make a number of predictions with very fair accuracy. (Fig. 2, page 52.)

Let A represent our maximum daily load.

Let B represent the maximum daily street railway load.

Let C represent maximum daily lighting load.

Let A B C represent the composite curve made up of the sum of all these curves.

This curve shows us that if the height of the point P measured upon a certain scale is X horsepower in June, the point P' is some Y per cent. greater in December. The difference between these two amounts of power will vary according to the character of the loads and the location of the market. But as we are going to be paid at the rate of the peak load horsepower furnished

during the year we are to be paid at the rate of P' horsepower. We are primarily interested in discovering how we can use the flow of water in the river to allow us to supply power represented by a curve having the general characteristics of $A\ B\ C$.

An inspection of the tables showing the flow of the stream may indicate that the minimum flow occurs in August or September. It at once be-

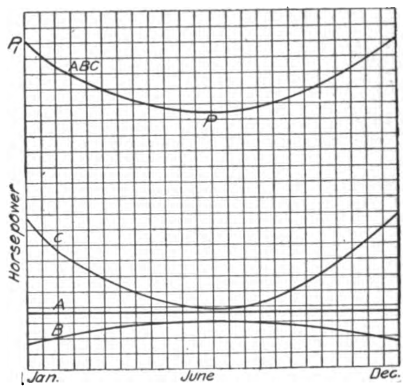
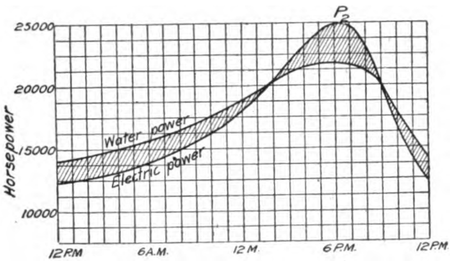


FIG. 2.

comes evident that these months must be studied carefully. Our estimated load curve shows that we may expect less load in July, so that since the flow in this month is greater than the minimum, this month will probably be provided for. We must now investigate how the flow increases from the low point during October and November and see whether it is at a fast enough rate to take care of the increasing load.

Fig. 2 shows the relation of the daily maximum peak loads and does not consider the length of time the peak lasts. To find this out we must analyze the kind of load we are to carry. We saw the commercial load was a ten-hour load, the main peak of the street railway load lasted for say five hours, etc. We must now plot a typical daily load curve for the least flow months.

Assume the curve on Fig. 3 is such a curve and shows that if we had some method of storing the



Pondage curve.

FIG. 3.

water from 12 night to 12 noon and liberating it through the wheels when needed, a much smaller flow of the river would be just as useful as if we had a larger continuous flow. The point P_2 is a point occurring upon the line $A\ B\ C$, Fig. 2.

The engineering investigation will show how much storage we are able to control. Should we have abundant pondage we may be able to carry a load represented by the curve on Fig. 3 with a less continuous flow of water than would be

equivalent to that necessary to carry P_2 if the load lasted for a long time.

Referring again to Fig. 2, line *A B C*, we find that under certain conditions the power obtainable from the least flow is much less than what we are going to get paid for. We have so far been dealing simply with daily amounts of water in any one year. Our next task is to study the variation in flow from one year to another. We shall find in general in studying the records showing flow of the river that one year was very low and the average low flow of a number of other years did not approximate this one unfavorable year. Should we find that the lowest flow year furnishes us with enough horsepower for our present demands, our investigation need proceed no further. We shall assume, however, that we desire to develop the maximum horsepower in the stream which will show a profit upon the sale.

We will next assume in order to bring out an example that the least flow year not considering pondage, etc., produced 10,000 hp. Upon taking averages of a group of other low years, excluding the lowest, we may find that we can produce say 15,000 hp. An average of all years at the low flow period may show an available flow of 17,000 hp.

A study of the situation may indicate that should we provide auxiliary generating machinery to make the lowest flow year equal the average low flow years that this machinery might remain idle twenty years before it would have one year of usefulness under the assumption that the future

can be judged by the past. If such should be the case it would be undoubtedly more advantageous to run the risk of paying damages caused by non-fulfillment of contracts than to allow this machinery to be idle. Now assume that we have made up our minds that it is a fair business risk to expect that we can, 15 years out of 20 say, get 15,000 hp. Let us, however, reduce this to 12,000, hp., since we may confidently expect, say 19 years out of 20, to be sure of this flow, and see what the result will be. We must provide from our earnings an insurance fund to guard against a 5 per cent. menace (once in twenty years) upon 12,000 less 10,000 or 2,000 hp., or one sixth of our product. The menace is, therefore, reduced to five sixths of one per cent. of the total power, or less than an ordinary fire risk. If we are going to supplement the river flow by either reservoirs or steam power, let us consider that we can safely call our normal flow 12,000 hp., since as we increase our output above the 12,000 hp., our proportionate menace decreases and consequently our rate of insurance.

For the purpose of this discussion we will take say 12,000 hp. as our normal flow. We now should make up a series of tables showing the number of cubic feet per second which would have to be added each day to the river to raise the horsepower of the stream from 12,000 to 15,000 hp., from 12,000 to 17,000 to 20,000 to 25,000, etc., according to the amount of power it is desired to produce.

Knowing the height of the fall, from these tables is readily calculated the amount of steam power

which must be held in reserve to bring the existing horsepower of the river up to the above figures, if steam is to be used as the auxiliary.

Reservoirs: The general conformation of the country along the river may be such that it is either impossible or utterly prohibitive on account of the cost to construct a reservoir or series of reservoirs. Upon the height of the fall which we get at the site of the proposed development and the manner of variation of flow of the stream will largely depend how much money can be spent for reservoirs. If it is possible to build reservoirs successfully we must know how much it will cost to construct these per horsepower of development.

Steam Power Auxiliary: The tables which were prepared showing the number of cubic feet which it was necessary to add to the flow of the stream in order to produce the various horsepowers which we were investigating, also showed, as already pointed out, the capacity of the apparatus which would be necessary to supplement the river flow. It may not be possible of course to build a supplementary power plant at the site where the water power development is to be made, but we will consider that some satisfactory place may be found where coal can be brought.

At such a place as may be chosen we must figure what it will cost to build a power house to supply 3,000 hp.; 5,000 hp.; 8,000 hp.; 13,000 hp.; in order to supplement the river flow. We may find upon making estimates that these installations would be at the rate of $100 per hp. Taking in-

terest, depreciation and taxes at 12 per cent. per year this would make a charge of $12 per hp. per year.

Now, as to the operation of the plant we must make up a calculation showing what it will cost per horsepower per year to furnish our auxiliary supply. An inspection of the load curves will probably show that a power house shift will have to work nearly 8 hours per day during the low flow months to handle the peak load. Assuming this period was 60 days, the station wages per hp. of station rating will probably not be far from $4 per year per hp., or 66 cents for two months.

The coal per horsepower-hour for this character of load will probably be high and may average from three to five lbs. The repairs will average somewhere about $2 per hp. per year or 33 cents for two months. The coal would probably figure 4 (lbs.) x 8 (hours) x 60 (days) or 1920 pounds for two months. This should be multiplied by the average percentage of a horsepower which was in use during 8 hours say 75 per cent. This equals 1440 lb. or 0.72 of a ton, at $4 per short ton amounts to $2.88 for the coal.

Summing up these figures:

Labor per hp. for 2 months	0.66
Repairs	0.33
Coal	2.88
Other expenses	0.10
Total	3.97

Adding the fixed charges of $12, the total cost of the auxiliary power is $15.97 per horsepower-year.

If it is fair to assume that money invested in such a business is worth about 6 per cent. If we capitalize $3.97 upon this basis it is equivalent to investing $66.16 per hp., to produce the reserve with which to supplement the river flow. In addition to this amount we must add the $100 per hp. for plant, making a capital expense per hp. of $166.16.

Although this figure looks very large to spend on auxiliary apparatus per hp., yet it is very likely that the cost of making the actual hydraulic development exclusive of the generating machines may not differ very much for 12,000 hp. or 25,000 hp. So that by supplementing the power by a relatively small auxiliary, working only a fraction of the total year, a very much increased amount of power can be sold at a fair rate.

We must now prepare a table showing what it costs to develop theoretical horsepowers, including reservoirs or steam auxiliaries. Thus:

12,000	hp.	cost	per	hp.	$A
15,000	"	"	"	"	$B
17,500	"	"	"	"	$C
20,000	"	"	"	"	$D
25,000	"	"	"	"	$E

In the final chapter of this book will be discussed the methods of choosing which one of these developments we should adopt so that the cost per horsepower will not exceed the amount which we can afford to invest.

CHAPTER IX.

CAPITAL COSTS.

Since we have made an extended examination of the costs of producing energy in different quantities in the districts which we desire to serve, we should be able to make fairly accurate estimates of the amount of business we can obtain at rates which will yield a satisfactory return upon the investment. The building up of a power business is at best somewhat slow and our estimates should consequently err on the conservative side.

The next table which should be prepared should be under the assumption that the power company is to supply all the profitable business which it can take at a definite price. The table would appear somewhat as follows:

TABLE I.

X	Horsepower	@	$A	per	hp.	=
Y	"	@	$B	"	"	=
Z	"	@	$C	"	"	=

etc., etc.

Average price received per horsepower-year = $

If the rates which have been estimated will get the business are not likely to be lowered in future, the above table gives us a fair indication of the business which the power company can eventually do.

We cannot expect to take all this business as

soon as the water power installation is complete but every preparation should be made for obtaining it as soon as possible. At the time the work of construction is begun, a force of solicitors and contract agents must be organized and sent into the field. The duty of these men is to begin negotiations for supplying electric energy and the closing of all contracts which can be made. The time set for taking on the business must be such that even if the work were delayed as usually is the case there will be no risk of endangering our contracts.

Contracts cannot probably be closed with the smaller customers but the "missionary" work must be all done so that they may be secured as soon as the plant is ready. A system should be organized by which all the information gained during the visits of the agents will be systematically recorded. One of the most simple methods is the use of a card catalogue upon which all the data, under the proper headings, is written. A reference number may be placed upon the card which refers to more detailed information, such as the results of engine and power tests, etc. A set of tables of obtainable business based upon the information secured by the contract agents and showing the probable results of the first four years of operation should be now prepared.

The operating costs can be approximately estimated from the information given in the previous chapter in discussing the various classes of service.

The results of the estimates may show that the cost of making the development is such that the operation of the plant for the first year or so, will not meet all charges, but the number of horsepower secured by contract may be such as to warrant every expectation of meeting all the interest charges within a reasonable time.

The deficit in interest charges while the plant is in partial operation is really in the nature of a capital charge and of course must be provided for in the capital requirements.

The results of our examinations show that the average price which the power company will receive for energy at the end of the fourth year will be, we will say, $35 per hp-yr.

An analysis of the nature of business engaged in may show the following:

	Per horsepower year.
Estimated average cost of demand.....	$ 6.00
" " " " supply.....	5.00
Total...........................	$11.00

This leaves net earnings of $24 per horsepower year. If we place the fixed charges at the following amounts as previously explained:

Interest upon investment............	5.5 per cent.
Depreciation due to change in art and advancement of science...........	1.5 per cent.
Insurance fund......................	1.0 per cent.
Repairs upon plant..................	1.0 per cent.
	9.0 per cent.

We find that $266 is the capital sum which will permit earnings of $24 at the rate of 9 per cent. The estimates may show that four years will elapse before the plant will earn its interest charges while probably not more than one-half the capital will be invested or not earning during this period, we must make an allowance for this fact. Considering money worth 6 per cent. in the construction period, the loss of interest will amount to one half of 24 per cent. or 12 per cent. If we deduct 12 per cent. from $266, there remains $234 which figure it is near enough to consider is the average amount of money that can be paid per horsepower of development. This sum, of course, represents one horsepower delivered at the customer's premises. Since there are numerous losses which take place between the customer and the power at the falls, the figure now derived must be modified to take account of the facts. Without going into the technical side of the question and speaking very broadly, a turbine working under average conditions, has an efficiency of from 70 to 90 per cent.

There are moreover losses in the dynamos amounting to a small amount. If we take the combined efficiency of a dynamo and turbine as 85 per cent., we probably shall be correct enough for commercial purposes. The transmission line will probably be designed to have no greater loss than 5 per cent. The sum of the losses in the step up and down transforms in commercial operation may be taken at about 5 per cent. When an

electric light company undertakes to distribute electric energy among many small customers it has been found that much the same thing takes place that happens in the case of a gas or water company. Namely, there is a difference between the number of units leaving the plant and those paid for by the customer. The horsepower-hours which the station meter shows have been generated are often 5 to 15 per cent. more than the amount paid for by the customers, the loss varying with the condition of the plant and the kind of business transacted. Since the plant will be new and the business one of wholesale rather than retail, let us take this loss at 5 per cent. The sum of all the losses indicated above amounts to approximately 30 per cent.

That is, 1.43 horsepower at the falls is approximately equivalent to one horsepower delivered to the customer. The number of horsepower sold is consequently very different from the number which it is necessary to provide at the falls. For instance the figure $234 per hp., the estimated amount of money which one can pay to be able to deliver one horsepower to the customer, is reduced by 30 per cent., so that the amount of money which is available for expenditure in terms of horsepower at the falls is about $163.00.

It frequently happens that the development of a water power can be best made in stages, that is in partial developments. If the first development were considered by itself it may happen that

the cost per unit horsepower would be so high that the receipts would not pay all the charges. Whereas by considering the second development we might find that the average cost per hp. was perfectly satisfactory. The question to be considered then resolves itself into one purely of time before the second development will come into use, and the basis of estimate outlined above may be used with modifications which would naturally suggest themselves to the reader.

The figure which has been derived by this calculation, namely, the amount of money which we can afford under given conditions to pay to develop a horsepower is obviously very necessary to know.

In applying the results of this calculation to any development in figuring the average cost per horsepower-year it is needless to point out that the number horsepower-year used is the number which may be sold and not necessarily the minimum flow of the stream.

We have seen in the course of this discussion that the amount of capital which may represent each horsepower-year offered for sale is dependent upon

1st. The yearly rental or gross revenue which we expect to receive for each horsepower rating of machinery installed.

2nd. The cost of rendering the service.

The yearly rental which we can obtain is dependent upon the cost of generating energy by the cheapest method applicable to the locality and

the number of hours per day the machinery is at the customers disposal.

The cost of rendering the service depends very largely upon the character of the business engaged in.

We have seen that one of the important expenses is the cost of demand. The cost of this service is as would be expected a very considerable amount per horsepower-year for lighting and small motors and decreases per horsepower in proportion to the size of the units supplied.

The cost of holding auxiliary machinery in reserve has been shown and also the items entering into the cost of supply.

The net revenue which remains after deducting all expenses, is the sum of money which must pay the interest upon the capital which represents each horsepower and also provide for the depreciation and losses.

The investment in water power enterprises is very attractive to many people who feel that there is no franchise limitation which makes the business one of limited duration, and that as time elapses it is not a wasting business like for instance, coal and other forms of mining from which diminishing returns must be considered. While there still remain in this country coal deposits large enough to last for a great number of years, yet the price of coal should tend to advance in time as the consumption increases and should counterbalance any cheapening of the cost of manufacture of electric energy from coal through the greater perfection in apparatus.

INDEX.